

N O T I C E

THIS DOCUMENT HAS BEEN REPRODUCED FROM
MICROFICHE. ALTHOUGH IT IS RECOGNIZED THAT
CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED
IN THE INTEREST OF MAKING AVAILABLE AS MUCH
INFORMATION AS POSSIBLE

(NASA-TM-78244) DEVELOPMENT AND TESTING OF
THE JUNKKEEPER CONTROL CORPORATION INTEGRATED
PROGRAMMABLE ELECTRONIC CONTROLLER AND
HYDRONICS PACKAGE Final Report (NASA) 21 p
HC A02/MF A01

N80-14495

Unclas
CSSL 10A G3/44 46453

DOE/NASA TECHNICAL MEMORANDUM

DOE/NASA TM-78244

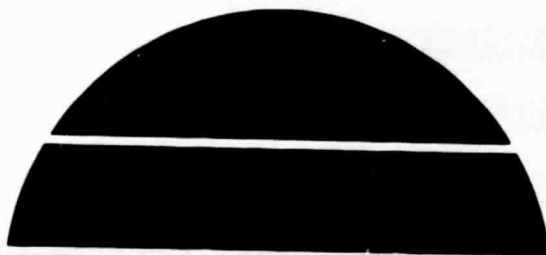
DEVELOPMENT AND TESTING OF THE SUNKEEPER CONTROL CORPORATION INTEGRATED PROGRAMMABLE ELECTRONIC CONTROLLER AND HYDRONICS PACKAGE - FINAL REPORT

By James D. Hankins

Solar Energy Applications Projects
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

1979

For the U.S. Department of Energy



U.S. Department of Energy



Solar Energy

TABLE OF CONTENTS

	Page
SUMMARY	1
INTRODUCTION	3
Program Background and Goals	3
Purpose of this Product Development Contract	3
DESCRIPTION	3
Project Development Requirements and Criteria	3
General Description of the Integrated Programmable Electronic Controller and Hydronic Sub-System	4
Programmable Electronic Controller	6
CONCLUSIONS AND RECOMMENDATIONS	10
APPENDIX — AS-BUILT SYSTEMS PERFORMANCE SPECIFICATIONS	11
APPLICABLE DOCUMENTS	15

PRECEDING PAGE BLANK NOT FILMED

LIST OF ILLUSTRATIONS

Figure	Title	Page
1.	Integrated Programmable Electronic Controller and Hydronics Package (I.P.E.C.H.).....	2
2.	Controller-Hydronics Subsystem Organization.....	5
3.	Programmable Electronic Controller.....	7
4.	Hydronics Module	9

DEVELOPMENT AND TESTING OF THE SUNKEEPER CONTROL CORPORATION INTEGRATED PROGRAMMABLE ELECTRONIC CONTROLLER AND HYDRONICS PACKAGE - FINAL REPORT

SUMMARY

The intended use for this report is to provide product development information as an aid to the solar heating and cooling systems manufacturing industry in their effort to determine the products adaptability for use in a specifically configured, total solar heating and/or cooling system for residential and commercial applications.

This report will also serve as an aid to those who desire to remain abreast of the state-of-the-art of solar energy heating and cooling projects.

The Sunkeeper Controller/Hydronics package, as developed under this contract, had its beginning in 1975, and was installed in a test home for single family use in late 1975. Sunkeeper continued to market these systems to gather expertise and factual test data. In November of 1976, Sunkeeper entered into a contract with the National Aeronautics and Space Administration (NASA)/George C. Marshall Space Flight Center (MSFC) to upgrade the Controller/Hydronics package to satisfy certain additional requirements to assure that the product could be classified as a marketable product and suitable for public use.

The deliverable end item under this contract was three identical subsystems (see Figure 1) consisting of a programmable controller, and a hydronic energy distribution and control package. The controller and hydronic equipment consists of modular components which may be integrated into a variety of configurations, yet housed in a single standard cabinet package.

At contract completion, three subsystems passed qualification and acceptance tests and were delivered to MSFC. These subsystems are marketable for solar heating and combined heating and cooling for large dwellings and commercial installations.

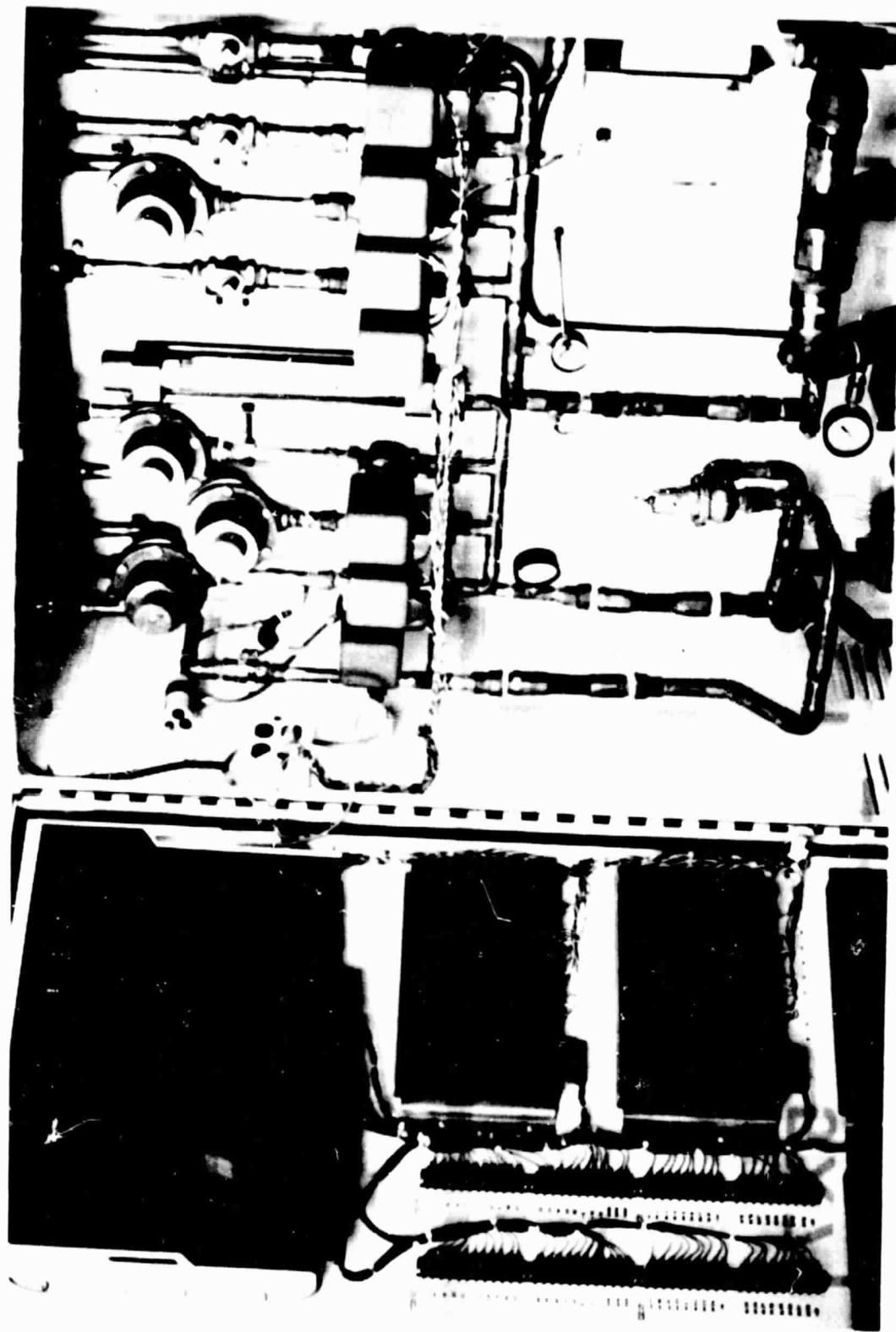


Figure 1. Integrated Programmable Electronic Controller and Hydronics Package (I.P.E.C.H.).

INTRODUCTION

Program Background and Goals

The problems of energy availability and increasing costs have led to a major national effort to develop alternate energy sources. One such source is the energy in solar radiation, which can be used for heating and cooling buildings, domestic hot water, and other applications. The National Energy Policy, as established in the Solar Heating and Cooling Demonstration Act of 1974 (PL93-409), provided for the demonstration of the practical use of solar heating technology within a 3-year period and demonstration of the practical use of combined heating and cooling technology within a 5-year period. Responsibility for implementing the Demonstration Act was given to the Energy Research Development Administration (now the Department of Energy). NASA/MSFC manages a large part of this work.

Purpose of this Product Development Contract

The purpose of this contract was to provide funding to the Sun-keeper Control Corporation to do additional design, development, fabrication, and test work on their existing subsystems (Integrated Programmable Electronic Controller and Hydronic Package) so that the subsystem can be classified as a reliable marketable product for public use.

This second generation system provides for completely modular elements and cost-effective hardware components. The subsystem consists of a programmable controller, and a hydronic energy distribution and control package which may be integrated into a variety of configurations, and are housed in a single standard cabinet package.

Contract performance period was from October 30, 1976 through September 17, 1978.

DESCRIPTION

Project Development Requirements and Criteria

During the development of the controller/hydraulics package the contractor was required to:

- 1) Meet the applicable parts of the interim performance criteria for solar heating and cooling systems.
- 2) Meet the subsystem performance specifications.

- 3) Provide test data and analysis to verify that hardware meets the subsystem performance specification.
- 4) Provide drawings and specifications in sufficient detail to define form, fit and function.
- 5) Provide installation, operation, and maintenance manuals.
- 6) Provide program execution plans, design review data, periodic status reports, and acceptance data packages.
- 7) Provide subsystem and/or component hardware certification by an independent test laboratory (such as Underwriters Laboratory and American Gas Association) to meet nationally recognized standards and codes (such as American Society of Heating, Refrigeration and Air Conditioning Engineers; American Society for Mechanical Engineers; American Standards Institute and American Refrigeration Institute).

General Description of the Integrated Programmable Electronic Controller and Hydronic Sub-System

The Hydronic (I.P.E.C.H.) sub-system (see Figures 1 and 2) is a completely assembled, piped, wired and tested package. It is designed to be used in large residential and small commercial solar heating and/or cooling applications. The package consists of three basic systems: (1) a power panel and programmable microprocessor, (2) a hydronic solar collection pumping system, and (3) a hydronic heating hot water pumping system.

The package requires only field connection of piping, power and sensor devices. It may be programmed to collect solar energy from the user's collectors based on a number of user determined inputs; such as, solar insolation, date, time of day, outdoor ambient conditions, etc. In addition, it may be programmed to heat various zones of the user's facility as determined by user installed zone thermostats or to store collected solar energy in user supplied storage tanks. Once user supplied inputs are connected, sequence of operation, set-points, and priorities may be changed at will without the need for field wiring changes.

The user may, through the use of a compatible portable printer terminal, have access to the controller either on site or remotely by a telephone modem. Access features include a 32-hr programmable interval history file of user selected data, print-out of all inputs and outputs, location of control sequence in program, ability to edit program and program printout. In addition, the controller may be connected to a remote master computer for data logging or master command, interrogation or program editing.

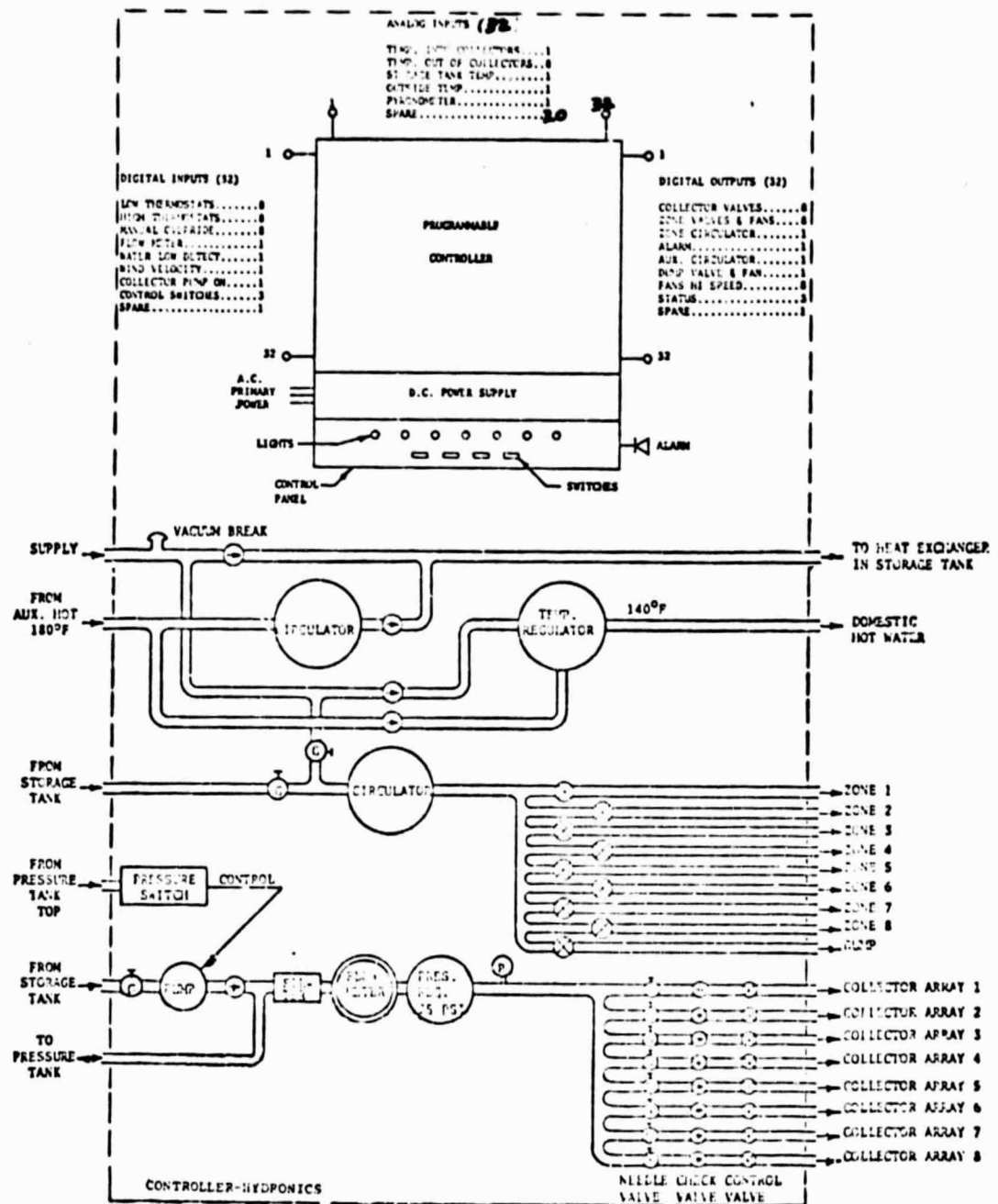


Figure 2. Controller-Hydronics Subsystem Organization.

Programmable Electronic Controller

The Processor section of the controller (see Figure 3) with appropriate memory provides the control and processing functions as dictated by the control algorithm software. The memory contains both ROM (fixed Read-Only Memory) and RAM (Random Access Memory) and is sized to allow application flexibility and future expansion, with cost effective tradeoffs.

The function of the controller is to accept analog and digital input signals, process the input data in a control algorithm and provide digital control output signals to the solar heating system hydronic and heating control elements. The input and output signal complement is:

32 Analog Input Channels

32 Digital Input Channels

32 Digital Output Channels

1 ASCII Data Transmit/Receive/Control Channel

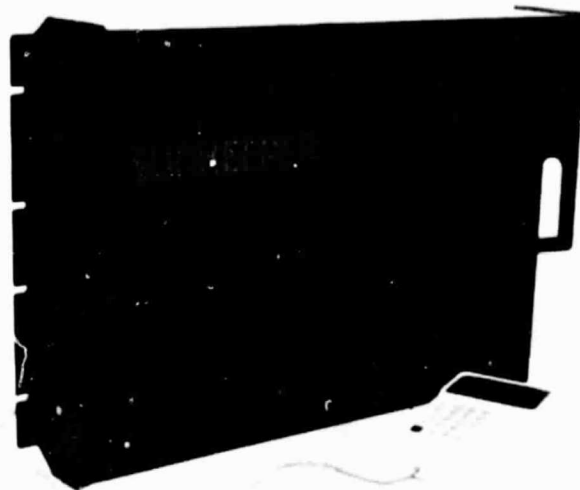
Up to 32 analog sensor voltage input signals are accepted by the controller. Analog input signals are generated by the various temperature or other sensing elements of the solar heating system. Analog-to-digital conversion of the input voltage signals are provided. Channel inputs are selected, converted and stored for processing by the control algorithm. Multiplexing of analog inputs are possible as an expansion of basic controller capability.

Up to 32 discrete digital input signals are accepted and processed by the controller. These signals are voltage level or pulses generated by "ON/OFF" type control functions, such as threshold level thermostats.

Up to 32 discrete digital output control signals are provided. These signals are voltage levels or pulses generated by the control algorithm to operate control valve and motor controls.

An ASCII compatible data channel is incorporated to provide an industry standard interface to communication equipment, other programmable controllers, computers, and computer peripherals. This function provides capability for remote monitoring and control of a solar heating system. It also provides the capability to use a cassette type data storage device loading of new or modified control algorithm software in the field, in lieu of new ROM's.

The clock generator in the controller contains a real time clock. In operation, the real time clock hardware provides continuous real time information throughout its 25-year life span. The clock is the only major component of the controller that is not controlled by either the master



ORIGINAL PAGE IS
OF POOR QUALITY

Figure 3. Programmable Electronic Controller.

program or the user's control sequence. The clock is extremely accurate and provides discrete time increments of tenths of a second, seconds, minutes, hours, time of day, week, month and year. The clock automatically compensates for leap years and months having 31 days. It never needs to be adjusted as long as power is not lost for longer than two consecutive days. A battery supply with an ac charging circuit will sustain the clock if the primary power is lost for the two days. If power is out longer than two days, it is easily reset and will continue to run with the same accuracy. The clock increments (seconds, hours, days, etc.) can be used by the user's control sequence for time clocking functions, step controlling functions, or to set time delays between energizing or de-energizing a series of items.

The dc power supply utilizes solid state technology for high reliability and long life; it is designed to deliver proper dc power to the processor and channel circuits regardless of anticipated variations in ac line voltages. In the event of a sustained power loss situation, the dc power supply and controller will shut down in a fail safe mode. Reset of the processor control sequence is automatic. The normal ac input configuration will be 117 V, 60 Hz.

A powerful, non-erasable master program is stored in the control unit's 8K of PROM memory. This factory supplied master control program allows the user to enter his particular control sequence program in the 16K of RAM memory. The combination of the master program and the user's control sequence provides the control for both the control unit and the energy system being monitored.

The master program can perform the following basic mathematical operations:

- Addition of analog input values
- Subtraction of analog input values
- Comparison of analog input values

Less than (<)

Greater than (>)

Equal to (=)

- Averaging of analog input values or percent of "on" time of digital output or bit values.

In addition, the master program can also solve the logic of a series of operations such as in the following statement: If the value of A less the value of B is greater than C, do a task.

The user's control sequence is a specific logical operation that takes into consideration all the variables affecting his system (temperature, time, switch settings, etc.). When certain conditions are met, the control sequences use the output lines to alter the operation of the system being monitored.

The master program of the control unit has the ability to perform data logging operations. This data logging permits the status of any combination (up to 16) of inputs or outputs to be sampled at selectable intervals. Upon request by the user, the log containing the averaged values of the monitored lines is printed out in a usable format.

To provide electrical control of motors, switches, actuators and other high power components, the low level controller signals are used to switch a high voltage and current element. As an improvement over components such as relays, the power control module is a solid state module using optically isolated triac switches. The module requires low power drive to achieve high current output and is highly efficient. The modules may be combined in groups up to 32 to suit the application interface.

In a solar energy collection system the temperature sensors are used in significant numbers as a control element. Eleven temperature sensors are typically required for an eight array, eight zone application. Sunkeeper experience with thermocouple units as sensors focused design attention on an improved low cost sensor approach. A sensor is implemented using a solid state thermistor. The sensor range is 0° to 300°F

with an accuracy of ± 1 percent. A cost advantage of this approach is the elimination of matching circuits and cable compensation requirements. The thermistor temperature curve compensation is amenable to linearization by a single software equation in the controller.

A key feature in the hydronic system is the modular assembly approach used in fluid distribution circuits (see Figure 4). There are three circuits per system: solar array water circulation, heating zone water flow, and domestic hot water. As shown in Figure 2, solar array circulation requires an individual array flow control (needle valve), a check valve, and a remote actuated ON/OFF valve. This circuit operates at low flow rates and low pressure; control is critical. The heating zone control requires a remote control valve for high flow and pressure. These circuits require highly reliable, low-power devices. The daily operating cycle rate is high and the duty cycle is high. Quiet operation and a low power consumption is necessary. The domestic hot water control requires a remote actuated ON/OFF valve which is operated infrequently, as required, in the event of system malfunction or manual intervention.

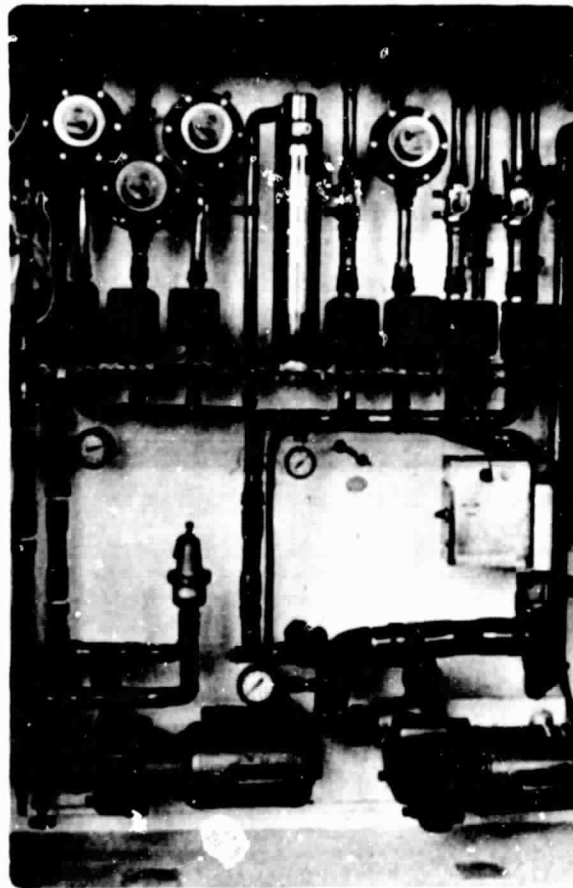


Figure 4. Hydronics Module.

CONCLUSIONS AND RECOMMENDATIONS

No major problems were encountered during this contract and the objective of the contract was successfully accomplished. The delivered controller/hydronics subsystems passed all acceptance testing and performance criteria. As a direct result of this contract, a later model Sunkeeper controller is on the market. The hydronics module is not available as an "off-the-shelf" item.

As of early 1979, 29 controllers had been installed in solar installations, operating approximately 60,000 sq ft of collectors in high technology commercial or experimental domestic applications where complex heating, cooling, storage, and load management systems are controlled. In addition, the built-in data acquisition capability of the controller is providing valuable performance data to the owners and designers of these solar installations.

The controllers are also being used, very cost effectively, in energy management and conservation applications. The microprocessor controllers have been installed in over fifty conventional buildings (10,000 to 300,000 sq ft).

The above 79 controllers are reducing conventional energy needs in excess of 12 billion Btu's per month through conservation and improved solar controls.

Andover Controls, Inc. of Andover, Massachusetts, should be contacted for additional information about the Microprocessor Controller (Sunkeeper) and/or the Hydronic Module.

APPENDIX

AS-BUILT SYSTEMS PERFORMANCE SPECIFICATIONS

ANDOVER CONTROLS CORPORATION
I.P.E.C.H. SUBASSEMBLY MODEL 1070
PERFORMANCE SPECIFICATION

SUBSYSTEM ENVIRONMENT

Temperature: 40° to 100°F
Relative Humidity: 5 to 95 percent
Primary Power: 117 ± 10 percent V, single phase, three wire
60 Hz, 30 amp service.

SOLAR COLLECTOR CIRCULATION SYSTEM

Flow Rate: 1.8 gal/min/zone ± 10 percent (total 15 gal/min)
Maximum Pressure: 30 psi
Pressure Head: 20 ft maximum
Fluid Temperature: 240°F maximum
Pump Control: Manual or Automatic
Pump Duty Cycle: Up to 100 percent, under program control
Automatic Valves: Eight electrically valved ports for array control
at 3.3 Cv/valve.

ZONE WATER SYSTEM

Flow Rate: 5 gal/min/zone ± 10 percent (total 40 gal/min)
Maximum Pressure: 30 psi
Pressure Head: 30 ft maximum
Fluid Temperature: 240°F maximum
Pump Control: Manual or Automatic
Pump Duty Cycle: Up to 100 percent, under program control
Automatic Valves: Eight electrically valved ports for array control
at 4.1 Cv/valve.

COLLECTOR PANEL MANIFOLD VALVE MODULE

Maximum Pressure: 125 psi
Valve Actuator: 6 W at 24 V
Valve Actuation Time: 15 sec maximum
Maximum Temperature: 240°F
Pipe Sizes: 3/4 in. output, 1-1/2 in. inlet

ZONE MANIFOLD VALVE MODULE

Maximum Pressure: 125 psi
Valve Actuator: 6 W at 24 V
Valve Actuation Time: 15 sec maximum
Maximum Temperature: 240°F
Pipe Size: 1 in. output, 1-1/2 in. inlet

PHYSICAL

Size: 34 in. D × 6 ft H × 4 ft W
Weight: Approximately 900 lb

DESIGN LIFE

Hydronics: 20 years
Controller: 20 years

ANALOG INPUTS

Thermistor: Quantity of 24, compatible with Fenwal type UUT43J1 bead
Voltage: Quantity of 8, 0 to 5.1 V, Z in > 3K

SWITCH INPUTS

Quantity: 32
Rising Threshold: 9.2 - 15.5 V
Falling Threshold: 1.75 - 7.3 V
Input Impedance: 1.5 K
State Definition: Open - Gnd = OFF
LED Indicators: Light when input is ON

DIGITAL OUTPUTS

Quantity: 32 (16 used to control I.P.E.C.H. zones)
(16 available to user)
Current Capability: 100 mA sink maximum
Voltage: Clamped to + 24 V, - 0.3 V
LED Indicators: Lights when associated output is closed to ground
(Sinks current)

VOLTAGES (Available to User)

+5, +24, ±12 V at 250 mA maximum each

OVERVOLTAGE PROTECTION

Inputs and Outputs withstand momentary short to 120 Vac.

MODEM CHANNEL

Interface: RS232-C
Baud Rate: Selectable 110, 300, 9600, or 19200

REAL TIME CLOCK

Calendar: Automatic calendar good to year 2000
Battery-Backup: Real time clock switches from 60 Hz line control to quartz crystal. Back-up good for two days minimum. Batteries recharge after power up.

PROGRAMMABILITY

The Sunkeeper control language simplifies the use of the controller capabilities. With a single statement, it specifies the analog and digital input conditions under which the unit turns digital outputs ON and OFF. The unit can also vary the action of the control programming depending on the time of day or time of year. It is also supported by 160 interval timers: 40 sec timers, 40 min timers, 40 hr timers and 40 days timers. Timers have a capacity of up to 256 units.

Analog input voltages are automatically converted to appropriate units so that limit points are in terms of degrees per volts. The automatic scaling simplifies the control programming and makes it easy to understand and maintain.

APPLICABLE DOCUMENTS

1. Preliminary Design Package for Programmable Controller and Hydronic Energy Package DOE/NASA CR-150629, Contract NAS8-32257, Sunkeeper Control Corporation, Andover, Massachusetts, April 1978.
2. Design Package for Programmable Controller and Hydronic Subsystem DOE/NASA CR-161151, Contract NAS8-32257, Sunkeeper Control Corporation, Andover, Massachusetts, March 1979.
3. Installation Package for Integrated Programmable Electronic Controller and Hydronic Subsystem DOE/NASA CR-150747, Contract NAS8-32257, Andover Control Corporation, Andover, Massachusetts, August 1978.
4. Proceedings of the First Workshop on the Control of Solar Energy Systems for Heating and Cooling, May 1978, pages 193-195, "Government Role in Development of Microprocessor Control Systems for Solar Heating and Cooling," by James D. Hankins, Marshall Space Flight Center, Huntsville, AL.


Documents 1, 2 and 3 can be obtained from the Department of Energy Technical Information Center (TIC), Oak Ridge, TN. Document 4 was published by the Publishing Office of the American Section of the International Solar Energy Society, Inc., McDowell Hall, University of Delaware, Newark, Delaware 19711.

APPROVAL

DEVELOPMENT AND TESTING OF THE SUNKEEPER CONTROL CORPORATION INTEGRATED PROGRAMMABLE ELECTRONIC CONTROLLER AND HYDRONICS PACKAGE - FINAL REPORT

By James D. Hankins

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.


WILLIAM A. BROOKSBANK, JR.
Manager, Solar Energy Applications Projects